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ART 34 AND

Disclosure of Invention

It is an object of the present invention to solve the above-described problems of the related art, and to present a zoom lens composed of four lens groups, in which camera shake can be corrected by shifting a third lens group that is fixed as a whole with respect to the image plane, in a perpendicular direction with respect to the optical axis when zooming and focusing. The zoom lens also can prevent degradation of chromatic aberration during correction of camera shake. The present invention presents a video camera and a digital still camera using this zoom lens, which can be smaller in size, lighter in weight and power-saving.

10 In order to attain this object, a first configuration of a zoom lens in accordance with the present invention includes:

a first lens group that includes a lens having negative refractive power and a lens having positive refractive power, as well as a lens having positive refractive power, arranged in that order from an object side to an image plane side, the first 15 lens group having an overall positive refractive power and being fixed with respect to an image plane;

a second lens group having an overall negative refractive power, a zoom operation being carried out by shifting the second lens group on an optical axis;

an aperture stop that is fixed with respect to the image plane;

20 a third lens group that is made of a lens having positive refractive power, as well as a lens having a positive refractive power, and a lens having negative refractive power, arranged in that order from the object side to the image plane side, the third lens group having an overall positive refractive power and being fixed with respect to the optical axis direction when zooming or focusing; and

25 a fourth lens group that is made of a lens having positive refractive power, a lens having negative refractive power and a lens having positive refractive power, arranged in that order from the object side to the image plane side, the fourth lens group having an overall positive refractive power and being shifted on the optical axis so as to maintain the image plane that fluctuates when the second lens group is shifted on the optical axis and when the object moves, at a certain position from a 30 reference plane;

wherein the second lens group is made of a concave meniscus lens, a concave lens, a double convex lens and a concave lens, arranged in that order from the object side to the image plane side, and includes at least one aspheric surface;

35 wherein the third lens group includes a cemented lens having a cemented surface whose convex surface faces the object side, the third lens group can be shifted in a direction perpendicular to the optical axis in order to correct image fluctuations

refractive power, arranged in that order from the object side to the image plane side, the third lens group having an overall positive refractive power and being fixed with respect to the optical axis direction when zooming or focusing; and

5 a fourth lens group that is made of a lens having positive refractive power, a lens having negative refractive power and a lens having positive refractive power, arranged in that order from the object side to the image plane side, the fourth lens group having an overall positive refractive power and being shifted on the optical axis so as to maintain the image plane that fluctuates when the second lens group is shifted on the optical axis and when the object moves, at a certain position from a  
10 reference plane.

The third lens group includes a cemented lens having a cemented surface whose convex surface faces the object side, and can be shifted in a direction perpendicular to the optical axis in order to correct image fluctuations during camera shake.

15 Furthermore, the second lens group, the third lens group or the fourth lens group includes at least one aspheric surface.

It should be noted that such an aspherical surface is defined by the following Equation 1 (this also applies to the following Second and Third Embodiments).

20 (Equation 1)

$$SAG = \frac{H^2/R}{1 + \sqrt{1 - (1+K) (H/R)^2}} + D \cdot H^4 + E \cdot H^6 + F \cdot H^8 + G \cdot H^{10}$$

25 In Equation 1, H denotes the height from the optical axis, SAG denotes the distance from the vertex on the aspherical surface at a height H from the optical axis, R denotes the radius of curvature at the vertex of the aspherical surface, K denotes a conic constant, and D, E, F, G denote aspheric coefficients.

30 It is preferable that the fourth lens group is made of a concave lens, a convex lens and a concave lens, arranged in that order from the object side to the image plane side, and that all of these lenses are cemented together.

In the zoom lens of this embodiment, all of the lenses in the fourth lens group are cemented together, and preferably, conditions of the following Expressions (1) and (2) are satisfied when  $\tau_{370}$  indicates transmittance of light having a wavelength of 370 nm and  $\tau_{380}$  indicates transmittance of light having a wavelength of 380 nm at a part of a lens where the thickness is 10 nm, the lens is the second in the fourth lens group when viewed from the object side.

$$0.02 < \tau_{370} < 0.2 \quad (1)$$

## CLAIMS

1. A zoom lens comprising:
  - a first lens group that includes a lens having negative refractive power and a lens having positive refractive power, as well as a lens having positive refractive power, arranged in that order from an object side to an image plane side, the first lens group having an overall positive refractive power and being fixed with respect to an image plane;
  - a second lens group having an overall negative refractive power, a zoom operation being carried out by shifting the second lens group on an optical axis;
  - an aperture stop that is fixed with respect to the image plane;
  - a third lens group that is made of a lens having positive refractive power, as well as a lens having a positive refractive power and a lens having negative refractive power, arranged in that order from the object side to the image plane side, the third lens group having an overall positive refractive power and being fixed with respect to the optical axis direction when zooming or focusing; and
  - a fourth lens group that is made of a lens having positive refractive power, a lens having negative refractive power and a lens having positive refractive power, arranged in that order from the object side to the image plane side, the fourth lens group having an overall positive refractive power and being shifted on the optical axis so as to maintain the image plane that fluctuates when the second lens group is shifted on the optical axis and when the object moves, at a certain position from a reference plane;  
wherein the second lens group is made of a concave meniscus lens, a concave lens, a double convex lens and a concave lens, arranged in that order from the object side to the image plane side, and includes at least one aspheric surface;
  - wherein the third lens group comprises a cemented lens having a cemented surface whose convex surface faces the object side, the third lens group can be shifted in a direction perpendicular to the optical axis in order to correct image fluctuations during camera shake, and includes at least one aspheric surface; and
  - wherein the fourth lens group comprises at least one aspheric surface.
2. The zoom lens according to claim 1, wherein the fourth lens group is made of a concave lens, a convex lens and a concave lens, arranged in that order from the object side to the image plane side, and all of the lenses are cemented together.
3. The zoom lens according to claim 1, wherein the fourth lens group is made

of three lenses and all of the lenses are cemented together, satisfying conditions of the following Expressions (1) and (2) when  $\tau_{370}$  indicates transmittance of light having a wavelength of 370 nm and  $\tau_{380}$  indicates transmittance of light having a wavelength of 380 nm at a part of a lens where the thickness is 10 nm, the lens being the second in the fourth lens group when viewed from the object side

$$0.02 < \tau_{370} < 0.2 \quad (1)$$

$$0.2 < \tau_{380} < 0.55 \quad (2).$$

4. The zoom lens according to claim 1, wherein conditions of the following Expressions (3) and (4) are satisfied when RIH indicates image height,  $f_1$  indicates a focal length of the first lens group, and  $f_2$  indicates a focal length of the second lens group

$$2.0 < |f_2 / RIH| < 3.0 \quad (3)$$

$$0.16 < |f_2 / f_1| < 0.22 \quad (4).$$

5. The zoom lens according to claim 1, wherein a condition of the following Expression (5) is satisfied when  $f_1$  indicates a focal length of the first lens group, and  $f_{11-12}$  indicates a combined focal length of a first lens and a second lens of the first lens group viewed from the object side

$$3.2 < f_{11-12} / f_1 < 5.0 \quad (5).$$

6. The zoom lens according to claim 1, wherein a condition of the following Expression (6) is satisfied when  $f_{13}$  indicates a focal length of a third lens of the first lens group viewed from the object side, and  $f_{132}$  indicates a focal length of a surface of the third lens of the first lens group facing the image plane viewed from the object side

$$-2.5 < f_{132} / f_{13} < -1.5 \quad (6).$$

7. The zoom lens according to claim 1, wherein a condition of the following Expression (7) is satisfied when  $dsag_{211}$  indicates an aspheric amount at the 10% effective aperture of an  $i^{\text{-th}}$  aspheric surface of the second lens group viewed from the object side, and  $dsag_{219}$  indicates an aspheric amount at the 90% effective aperture of an  $i^{\text{-th}}$  aspheric surface of the second lens group viewed from the object side

$$-0.23 < dsag_{211} / dsag_{219} < -0.10 \quad (7).$$

8. The zoom lens according to claim 1, wherein the aspheric surface of the second lens group is a surface arranged closest to the image plane side, and the

aspheric surface being the concave surface that faces the image plane side.

9. The zoom lens according to claim 1, wherein a condition of the following Expression (8) is satisfied when  $dsag_{3i1}$  indicates an aspheric amount at the 10% effective aperture of an  $i$ -th aspheric surface of the third lens group viewed from the object side, and  $dsag_{3i9}$  indicates an aspheric amount at the 90% effective aperture of an  $i$ -th aspheric surface of the third lens group viewed from the object side

$$-0.24 < dsag_{3i1} / dsag_{3i9} < -0.15 \quad (8).$$

10. The zoom lens according to claim 1, wherein a condition of the following Expression (9) is satisfied when  $dsag_{4i1}$  indicates an aspheric amount at the 10% effective aperture of an  $i$ -th aspheric surface of the fourth lens group viewed from the object side, and  $dsag_{4i9}$  indicates an aspheric amount at the 90% effective aperture of an  $i$ -th aspheric surface of the fourth lens group viewed from the object side

$$-0.45 < dsag_{4i1} / dsag_{4i9} < -0.13 \quad (9).$$

11. The zoom lens according to claim 1, wherein a condition of the following Expression (10) is satisfied when RIH indicates an image height,  $Sg_i$  indicates a specific gravity of each lens and  $CL_i$  indicates a lens diameter of each lens in the third lens group

$$\sum_{i=1}^n (Sg_i \cdot CL_i^2) / RIH < 50 \quad (10).$$

12. A video camera comprising a zoom lens, wherein the zoom lens used is according to any of claims 1-11.

13. A digital still camera comprising a zoom lens, wherein the zoom lens used is according to any of claims 1-11.